The NASA Space Network Demand Access System: A Building Block Toward the Space Internet

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Abstract

The Demand Access System (DAS) currently under development by National Aeronautics and Space Administration (NASA) Goddard Space Flight Center (GSFC) will provide DAS Customers with the capability of receiving return telemetry data from a spacecraft via an Internet Protocol (IP) based network, including in the future, the Internet. DAS uses an extended version of the legacy Tracking Data and Relay Satellite System (TDRSS) Multiple Access Return (MAR) ground processing to select and demodulate return signal data obtained from the onboard Tracking and Data Relay Satellite (TDRS) Multiple Access (MA) antenna. When operational in 2002, DAS Customers will request services on demand via the Internet without going through the normal TDRSS service scheduling process. Currently, DAS does not employ an intelligent router that is capable of dealing with messaging protocols to distribute return data to DAS Customers. Instead, DAS relies on an equipment service scheduling controller to make a real-time correspondence between the generation of return data bit-stream ground based TCP/IP packets and the assignment of customer specified Internet destinations. The current DAS role with the Internet is limited to forming and distributing Internet packets that transport bit-stream telemetry data to customer specified Internet/NASA IONet destinations.

The current DAS can be considered a foundation upon which an end-to-end Space Network (SN) Internet can be established to serve DAS Customers as well as serving the future needs of autonomous spacecraft-to-spacecraft communications. The key to broadening the role of DAS relative to Internet communications lies in the development of an automated forward link capability, an space segment Internet protocol, and an intelligent routing capability that addresses the problem of distributing messages to orbiting spacecraft. An automated forward link capability would add a capability that allows both DAS Customers and autonomous spacecraft to send Internet messages to spacecraft. This new capability presupposes the existence of a common Internet protocol that allows the bi-directional flow of information between customers and their spacecraft as well as between spacecraft.

1. DAS Overview

The DAS is an MAR service system that is currently under development. It enhances the legacy TDRSS MAR service system by expanding the fixed limit of 5 simultaneous return services per TDRS to handle a virtually unlimited number of simultaneous services. DAS Customers enter requests for return services through an Internet based interface and they receive their return telemetry data via the Internet. DAS Customers submit service requests directly to the DAS Controller located at the White Sands Complex (WSC) via an Internet Web based interface. The DAS Controller translates DAS Customer requests for MAR services into specifications that designates beamformers, demodulators, and routing information needed to establish a return data pipeline to the customer. The controller automatically orchestrates the allocation of pooled DAS resources to form the equipment chain needed to support each DAS Customer's service.

As shown in Figure 1, DAS provides virtual MAR global coverage for DAS Customer emitters in view of one or more TDRSs). Since DAS data recovery equipment is located at the White Sands Ground Terminal (WSGT), the Second TRDSS Ground Terminal (STGT), and the Guam Remote Ground Terminal (GRGT), it is possible for an orbiting emitter to establish virtually continuous return data pipeline between the emitter and the DAS Customer Mission Operations Center (MOC) as the emitter orbits the Earth.

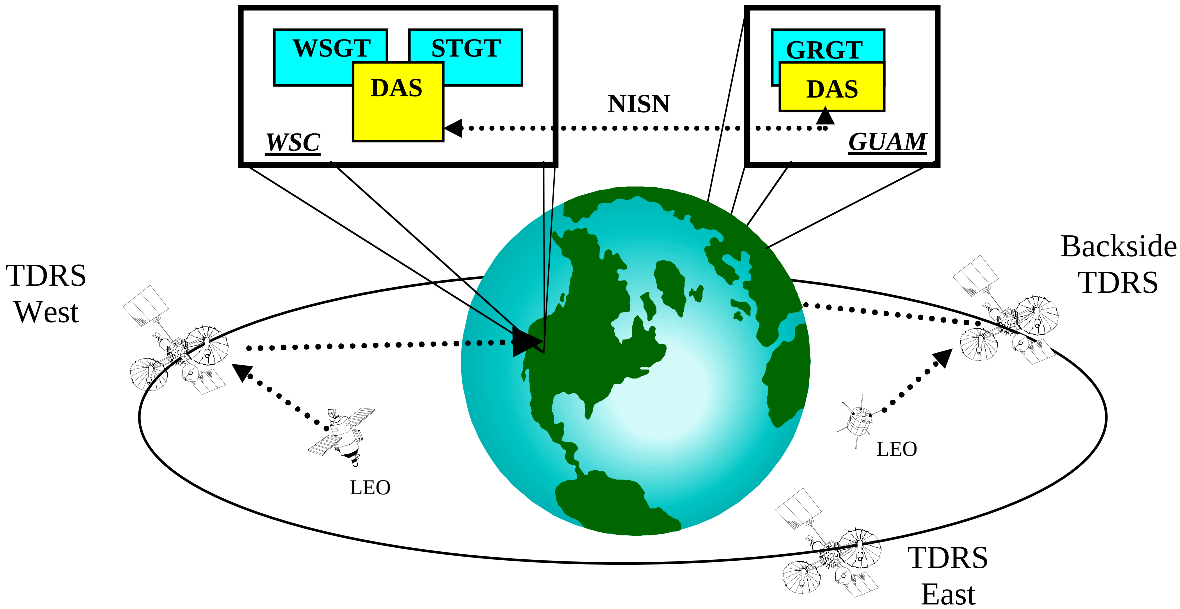


Figure 1. DAS MAR World-Wide Return Service Coverage

1.1. Return Data Recovery

Each TDRS satellite is equipped with a MAR phased array antenna consisting of 30 elements. All satellite RF signals at the TDRSS MAR frequency incident on the phased array are downlinked to a TDRSS ground terminal for down conversion to IF for beamforming processing. As shown in Figure 2, return data recovery is accomplished by directing the MAR IF signal output from the legacy TDRSS SN equipment located at an SGLT into DAS Individual Beamforming Units (IBUs). The IBUs process the IF signals by applying delays to the 30 channels of IF signals associated with each of the elements on a TDRS multiple array return antenna. The delays are determined by the use of the relative spatial positions of a TDRS and a DAS Customer's emitter platform obtained from orbital data. The application of the delays to the IF signal processing spatially isolates the DAS Customer's platform thereby providing a ground based processing beam. The beam formed by an IBU contains all signals from a region of space targeted by the processing operations. The addition of IBUs allows the simultaneous extraction of spatially diverse platforms by forming a virtually unlimited number of different ground based processing beams from the single IF beam obtained from a single TDRS RF downlink. Directing the output of each IBU to a demodulator allows the return data from a specific emitter to be extracted from the IF signal when the appropriate demodulation parameters are applied to the

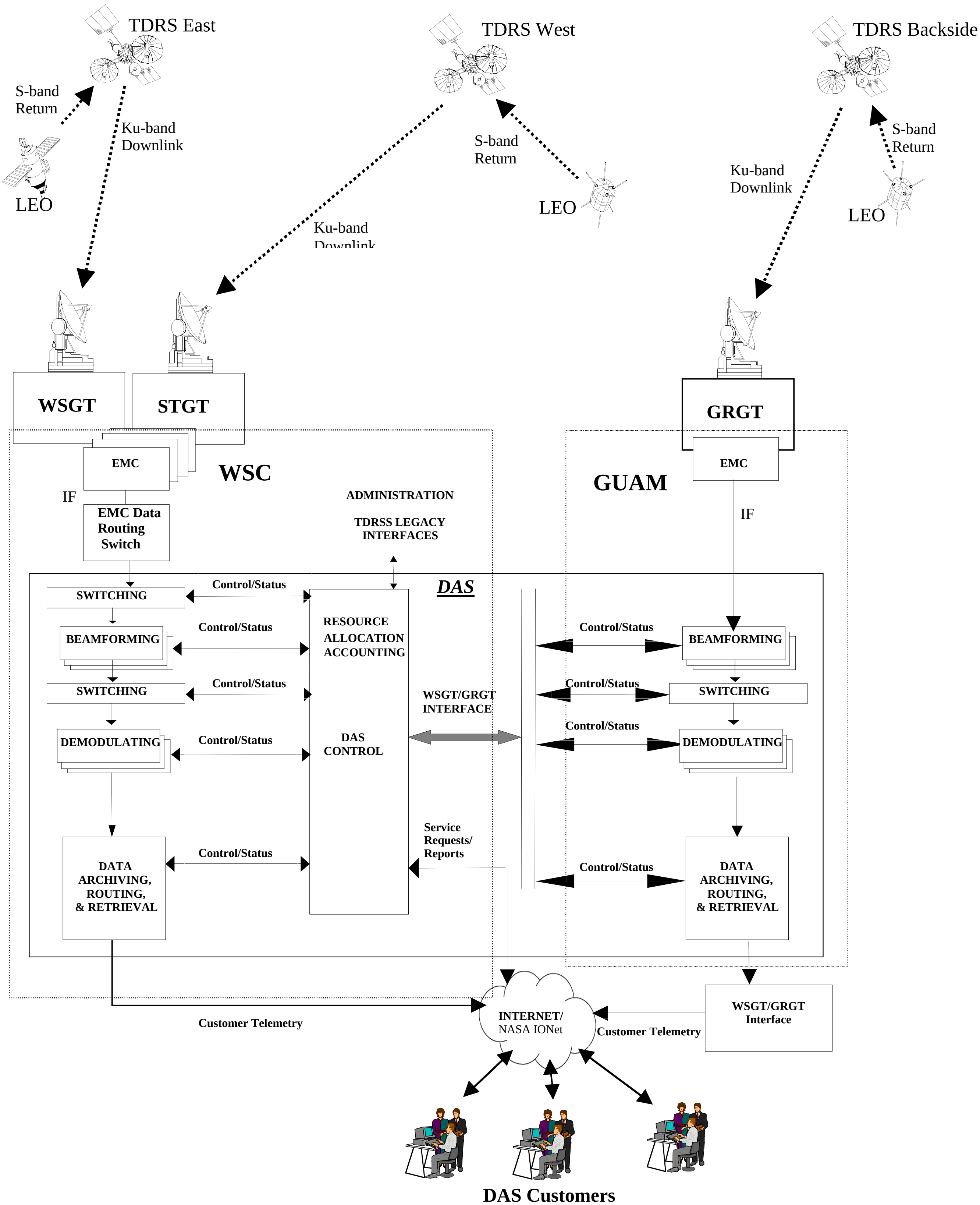


Figure 2 DAS Architecture and Legacy TDRSS Interfaces

demodulator (PN code, data rate, etc.). The output of each demodulator is a bit-stream of digital data recovered from the ground based processing of the return signal. The DAS Controller is responsible for coordinating the beamforming and demodulation functions in order to meet a DAS Customer's service request.

1.2. Return Data Distribution

The DAS Controller at WSC schedules world-wide DAS resources to make TDRS handovers virtually transparent to the DAS Customer. Since DAS data recovery equipment is located at WSGT, STGT, and the GRGT, it is possible to establish virtually continuous return data pipeline between an emitter and the DAS Customer MOC at all points in the satellite's orbit. As shown in Figure 3, the return telemetry data output from the demodulators are distributed to DAS Customers via the Open and Closed IONets. Demodulator service assignments are correlated with DAS Customer specified IP addresses by the DAS Controller and supplied as a service specification to the DAS distribution function. The distribution function captures the bit-stream data from each demodulator and appends it to a TCP/IP header containing the customer supplied IP address. The data packet is sent over the Internet to the DAS Customer.

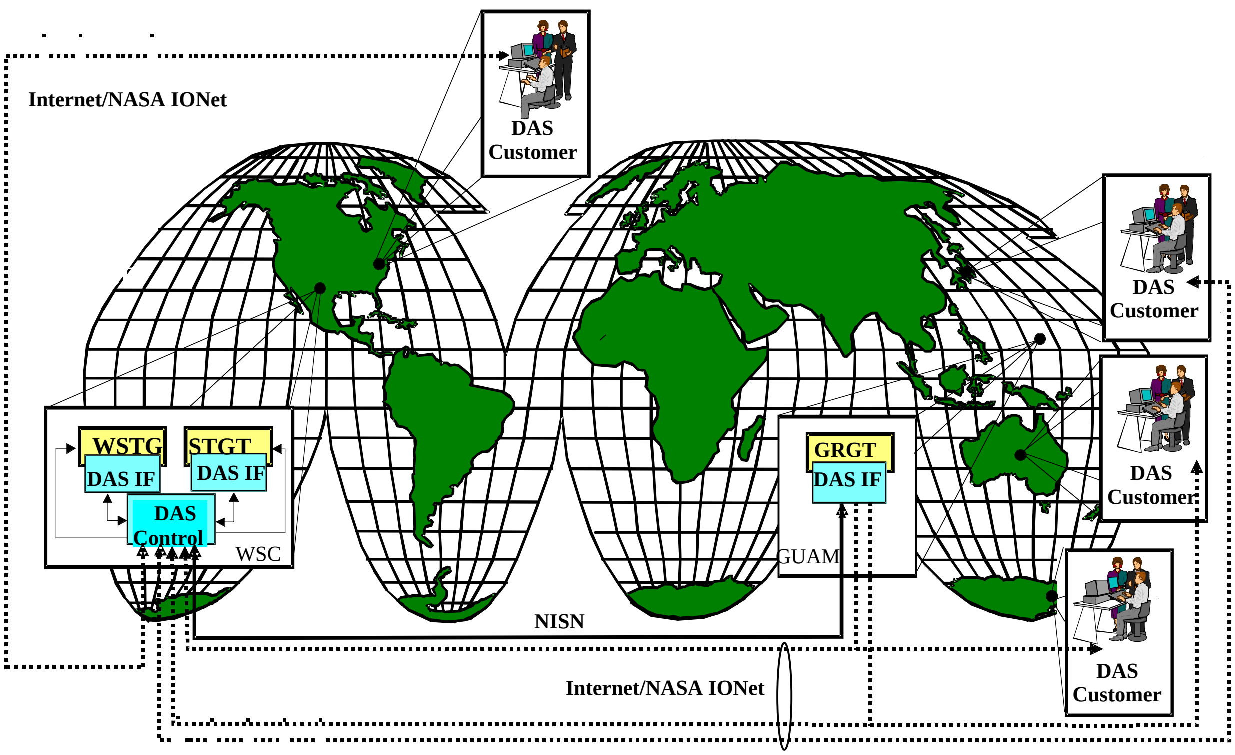


Figure 3. DAS Return Data Distribution to DAS Customers via the Internet

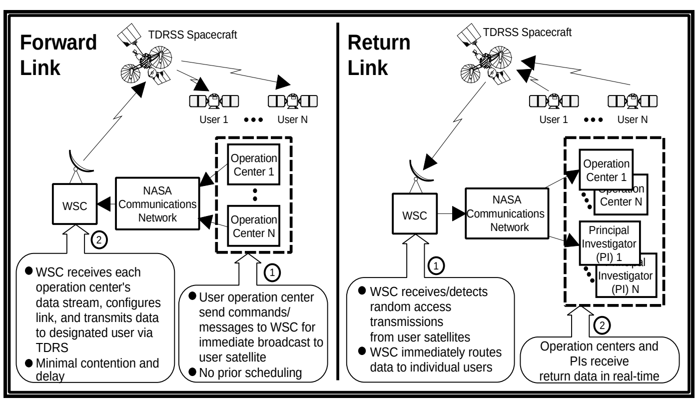
2. Upgrading DAS to Perform Two-Way Information Transfers

The version of DAS currently being developed supports a one-way Internet transfer of data from customer emitters to customer MOCs. In order for DAS to support a two-way data transfers between DAS Customers and their emitters, the MA forward TDRSS must be integrated into

DAS operations. In addition, a transport session layer must be added to support two-way messaging. Figure 4 illustrates the high-level features of both DAS based forward and return link operations.

In order to support a two-way capability, it is necessary to introduce a completely automated forward service capability to augment the current DAS return capability. Automation implies that commands and data can be sent to a satellite without going through a manual scheduling process of the legacy TDRSS or any other process involving manual DAS Customer interactions by a single request installation. Unlike the MAR service, each TDRS supports only one Multiple Access Forward (MAF) service at a time.

The normal approach to current forward scheduling in the legacy TDRSS is based on a prioritized, Network Communications Center (NCC) orchestrated manual system that can require several weeks of lead-time to schedule a forward service. After a forecast schedule becomes available, the unscheduled TDRSS resource time is determined. Unused available service time is presented daily via a Web page and e-mail announcements to legacy system customers to be used for short term scheduling add options. The TDRSS Unused Time (TUT) options are made available to legacy customers on a first come, first serve basis. This method of obtaining a MAF service during TUT periods has been partially automated as part of an advanced DAS operations inter-satellite communications concept feasibility demonstration [1]. For the experiment, TCP/IP messages were relayed by a TDRS from a fixed transmitter (representing the source satellite) to a computer at Reston, VA via the MAR service and the Internet. Upon receiving of the message, the computer forwarded the message via the Internet to WSC for uplinking to a TDRS for relay to a fixed receiver (representing the destination satellite). MAR service time had to be arranged with the GSFC NCC in order to perform the experiment. The automatic acquisition of TUT time could be easily automated to eliminate the need for human intervention in the satellite-to-satellite to data exchange.



3. Figure 4. DAS Forward and Return Operations

Besides adding a forward MOC to satellite service capability to the existing DAS return service, total forward automation will pave the way for a new TDRSS satellite-to-satellite communications capability that would allow satellites to communicate with each other with or without line-of-sight visibility conditions. Figure 5 shows two service scenarios concepts that would become available with DAS total forward automation.

Concept 1 represents the natural extension of legacy TDRSS MA services in the sense that commands and data are sent from the customer's MOC to the target satellite on the forward link. The satellite in turn sends return telemetry data. to the MOC. DAS differs from the legacy

TDRSS MA services in that it provides a totally automated forward service on demand, which eliminates the need for the relatively long lead-time prioritized service scheduling. The concept illustrated in Figure 4 shows a message being path from a satellite to the MOC via the DAS return service currently under development. A forward message is then sent from the MOC to the same satellite or another satellite. This path assumes the use of the current partially automated TDRSS MA service. This scenario requires a certain amount of manual activities at the MOC to setup the forward service to complete the eight steps illustrated in Figure 5.

Concept 2, satellite-to-satellite information exchange without the MOC being involved, is a new service capability founded on an intelligent message routing function that would be added to DAS. The difference between Concept 1 and two lies in the capability to automatically forward a message from one satellite to another without any MOC intervention. DAS satellite-to-satellite information exchanges suggest that common messaging protocols would be introduced on the Space Segment side of TDRSS and that DAS would become a gateway between the Earth-based Ground Segment Internet/NASA IOnet and a TDRSS Space Segment Satellite Internet.

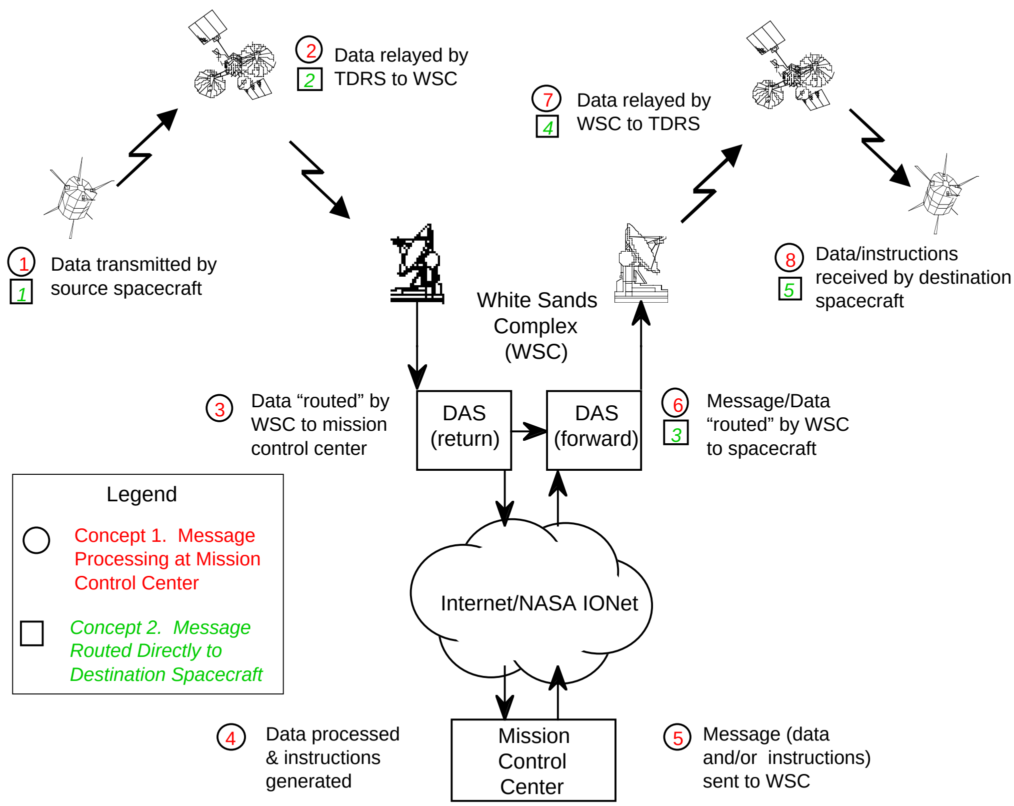


Figure 5. Expanded DAS Concepts for Combined Forward and Return Link Communications

3. Space Segment Satellite Internet

Satellite to satellite information exchanges suggest the development of a TDRSS Space Segment Internet. In order to share information on a TDRSS Space Segment Internet, participating satellites must be capable of sending and receiving messages that use the same protocols. The Space Segment Protocol would most likely differ from that of the Segment Protocol suggesting the need for protocol translations between these segments for the cases where a message pass through the DAS gateway that provides the interface between the two segments. Since satellites typically carry multiple payloads of equipment, it is the on-board payload on one satellite that would engage in communications with the on-board equipment of another satellite. Each satellite would have its own on-board LAN with a router that would direct the incoming messages to and outgoing messages from the target equipment. Each set of equipment (science experiment, on-board controller, etc.) would have its own IP address. Scientific and engineering telemetry data would be packetized for delivery to other nodes on the Space Segment Internet or to Ground Segment Internet nodes such as MOCs and alternative destinations designated by the MOCs controlling the on-board equipment. Science alerts and other shared information would be sent across the Space Segment Internet to other cooperating satellites.

4. Intelligent Message Routing

The implementation of the DAS currently under development extracts bit-stream data from the MA return signal and packets into TCP/IP message frames for delivery to DAS Customer destinations over the Internet/NASA IONet. As such, the current routing capabilities do not include an assessment of the message content to make complex routing decisions. The DAS routes return telemetry data to DAS Customer destinations by correlating the output of a specific demodulator with the associated destination IP address provided by the DAS Controller. In order to provide a two-way flow of information between the DAS Customers and satellites an intelligent routing will have to be added to the current DAS system. Figure 6 illustrates the high-level steps involved in implementing the intelligent routing process for two-way message transfers between MOCs and satellites as well as inter-satellite exchanges.

While fixed destinations on the Earth's surface present no special concerns to DAS Internet message routing, satellite destinations have an additional orbiting constraint placed on the routing algorithm that must be addressed. This constraint is due to the intermittent visibility of the satellite from a specific TDRSS ground terminal. Routing forward messages to a satellite requires the additional knowledge of where the satellite is currently visible with respect to WSGT, STGT, and GRGT. The routing decisions must include where the satellite is located relative to the ground terminal in order make a timely decision needed to forward the data to the target satellite. This requires that the DAS router access visibility information derived from the satellite's ephemeris in order to determine which ground terminal to select for uplinking messages to the target satellite at any given time. In addition, forward TUT must be evaluated to select a time slot that simultaneously satisfies both visibility and forward service availability constraints to set up the message exchange. This type of automated schedule assessment functionality is currently designed into the DAS Controller a WSC for managing the return service scheduling of the pooled resources at WSGT, STGT, and GRGT. Figure 5 illustrates the high-level steps involved in implementing the intelligent routing process for two-way message transfers between MOCs and satellites as well as inter-satellite exchanges.

The intelligent router operates as a gateway between a Space Segment DAS Customer satellites and the Internet/NASA IONet operating within the Ground Segment. Another role of the intelligent router would be to perform the protocol translations, if required, for both directions of message transfer between the two systems assuming that the Space Segment Internet and the Ground Segment Internet are not directly compatible as far their protocols are concerned.

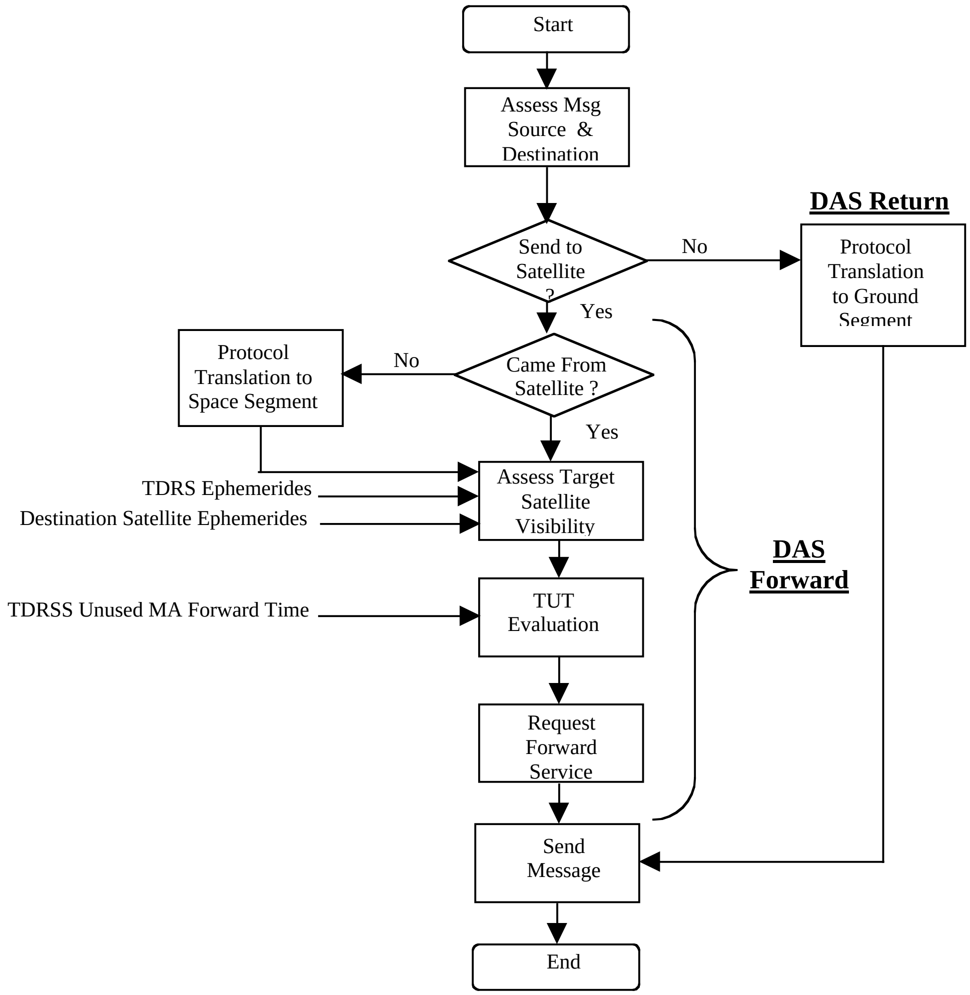


Figure 5 High-Level Two-way Intelligent Routing Logic Process Steps

5. Summary

The current DAS development effort supports a simplified version of one-way TCP/IP return data distribution in the Ground Segment portion of the SN. The distribution is not based on the receipt of TCP/IP data packets from the Space Segment that are then routed to DAS Customers on the basis of their IP addresses. Instead, demodulated bit-stream data is fragmented into segments and inserted into TCP/IP frames. The customer specified return data IP address are inserted in the packets and the messages are distributed by the DAS across the Internet/NASA IONet.

A generalized approach to introducing an end-to-end Internet capability to the SN involves the bi-directional exchange of TCP/IP packets between satellite payloads and MOCs as well as inter-satellite exchanges. Rather than dealing with bit-stream transfers, all transactions would take place via data source generated Internet message packets. The DAS router would be upgraded to evaluate the destination address from the return data message packet and use that to direct the routing of the packet to the DAS Customer. Likewise, forward message packets sent from a MOC to a satellite or from one satellite to another would become feasible. The use of an intelligent router could support spacecraft-to-spacecraft data exchanges where cross-links are not feasible such as in the cases of satellites out of view of one another due to Earth blockage. This type of Internet capability assumes the existence of two-way data exchanges, common protocols, and an intelligent router that supports fixed as well as mobile SN Internet nodes. The current development version of the return service DAS provides the basic foundation upon which a forward service can be added. The versatility of a DAS two-way messaging capability could be leveraged further to provide a Space Segment Internet infrastructure that allows DAS Customers and TDRSS user satellites to exchange information among themselves using standard protocols.

References

1. Phil Librecht, Angelita C. Kelly, Roger Flaherty, Mark Schoeberl, William D. Horne, and David Zavetz, “Satellite Internetworking and Messaging in Support of the Earth Science Constellation”, SpaceOps2000, Toulouse , France, June 2000.